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WATER QUALITY TELEMETRY

Duard S. Woffinden, et al

Utah Water Research Laboratory
Logan, Utah

August 1968

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Water Quality Telemetry

First Annual Progress Report

By Duard S. Woffinden and Allen D. Kartchner

This project was supported in part by a Water Supply and Pollution Control Demonstration Grant No. WPD 179-01-67 from the Division of Research and Training Grants, Federal Water Pollution Control Administration

Utah Water Research Laboratory / College of Engineering
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GENERAL PROJECT DESCRIPTION

Project Objectives

The primary objective of the project is to demonstrate the feasibility of telemetering, by radio transmission, several water quality parameters from remote, battery operated, monitoring stations to a central receiving station. The initiation of each transmission is accomplished by signaling the remote monitoring station from the central receiving station. It is thus possible to monitor the quality parameters at any remote location at any given time. Battery operation allows remote stations to be placed according to quality requirements without restrictions due to power availability.

Two field stations have been installed in the Little Bear River, one at Wellsville and the other at Paradise. Both stations have consistently transmitted data to the central receiving station upon interrogation. The accuracy and reliability of the transmitted data have been verified by on-site surveillance tests. Parameters that have been measured are electrical conductivity, pH, dissolved oxygen, and water temperature.

A secondary objective of the project is to show the economic feasibility of establishing and maintaining a remote, battery-operated field station. Excluding development, the cost of a typical field station is approximately $5500.

During the development period, weekly maintenance, consisting of cleaning electrodes, occasional battery replacement, and checking instrument calibration, was conducted. After completion of the development phase, maintenance visits could be more infrequent, perhaps once a month.

In the process of constructing and instrumenting these two field stations, much valuable experience has been gained and many potential improvements have been noted. An improvement in performance, size, and cost could be accomplished by integrating the analyzing circuitry for the sensing elements into a single unit instead of using separate analyzer units as was done for this project. This improvement would be facilitated by recent developments in the field of solid state electronic components and integrated circuit systems, and should be done before a multisite water quality monitoring system can become economically attractive. Automatic multisite systems will certainly be necessary before effective water resource management can be instituted in most states.

The project described by this report is an important beginning step in the establishment of an effective field data gathering network.

System Description

The demonstration system consists of two field sites on the Little Bear River and a central base station at the Utah Water Research Laboratory. One field site is located near Wellsville, Utah, downstream

from the Wellsville sewer outfall. The other site is located near Paradise, Utah, downstream from a trout farm.

Each field site system is contained in a metal shelter mounted on a concrete pad poured on the river bed. The Wellsville shelter is shown in Fig. 1. A hinged door provides access to the enclosure, and a tube mounted on the side of the shelter supports the radio antenna mast. Fig. 2 shows the access door and the antenna mast in the support tube for the Paradise station.

The water quality analyzer instrumentation, radio telemetry module, and batteries are accommodated by three shelves in the top of the enclosure as shown in Figs. 3 and 4. The canister container in the left side of the shelter contains the telemetry receiver-transmitter, the switching and conditioning circuitry, and the telemetering system battery. The separate commercial analyzers are shown to the right and below the telemetry module with their associated batteries on the top shelf. The radio antenna mast installation is shown in Fig. 5 for the Paradise station. The analyzer sensors are mounted on a float which is shown in Fig. 6. Sufficient vertical travel of the float is allowed to accommodate expected high and low water conditions. Typical sensors are shown in Fig. 7.

The base receiving station is located at the Utah Water Research Laboratory in Logan. A 75-foot receiving antenna tower is located at the laboratory (see Fig. 8). The incoming radio frequencies are aurally

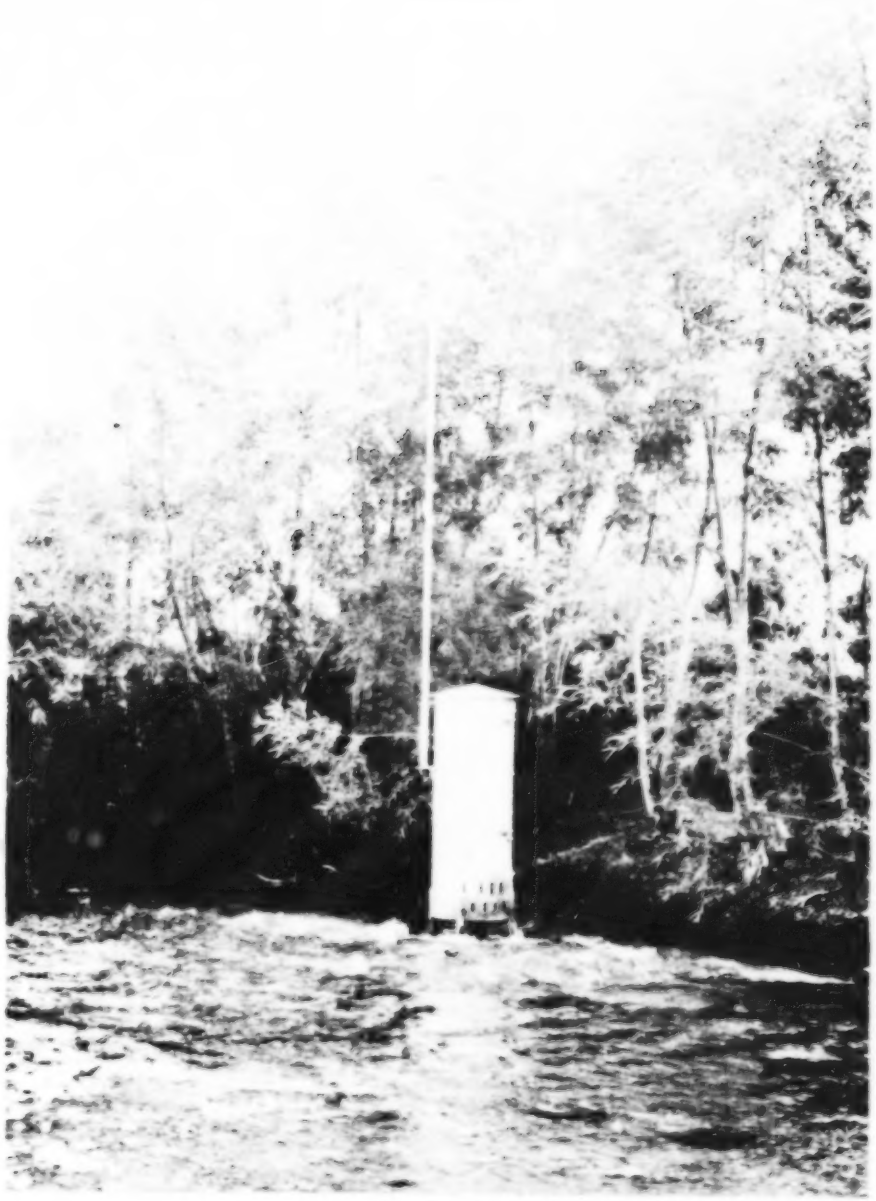


Fig. 1 Wellsville station installation

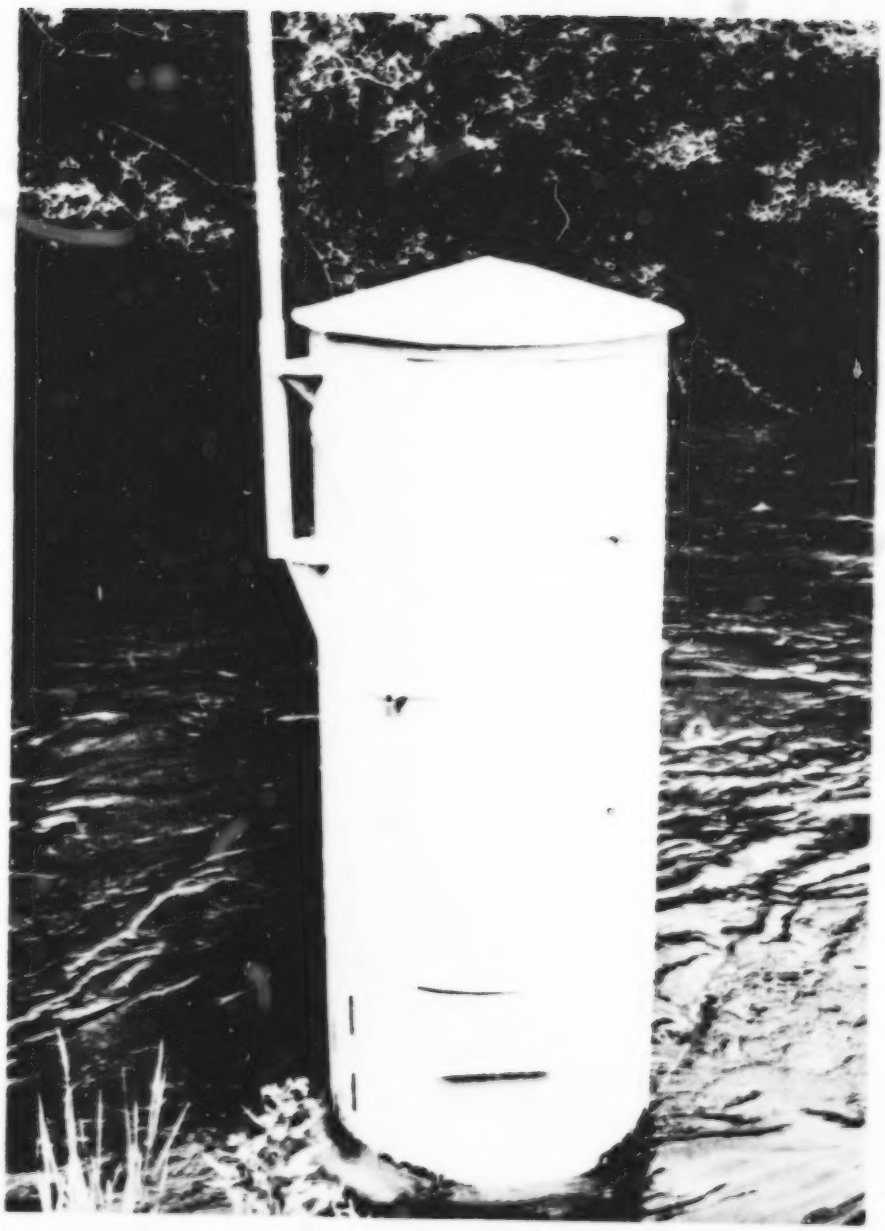


Fig. 2. Access door and antenna mast mount at Wellsville.

Fig. 3. Interior view at Wellsville station.

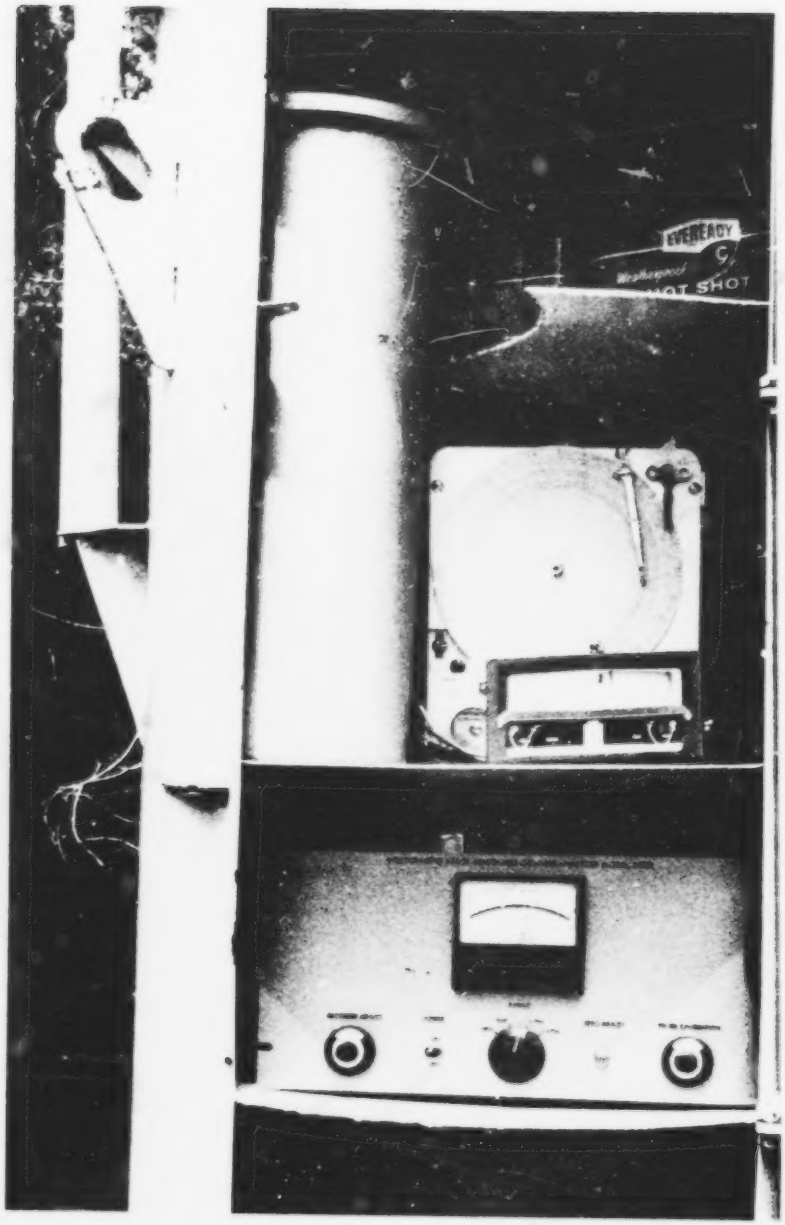


Fig. 4. Close-up view of Wellsville station interior.

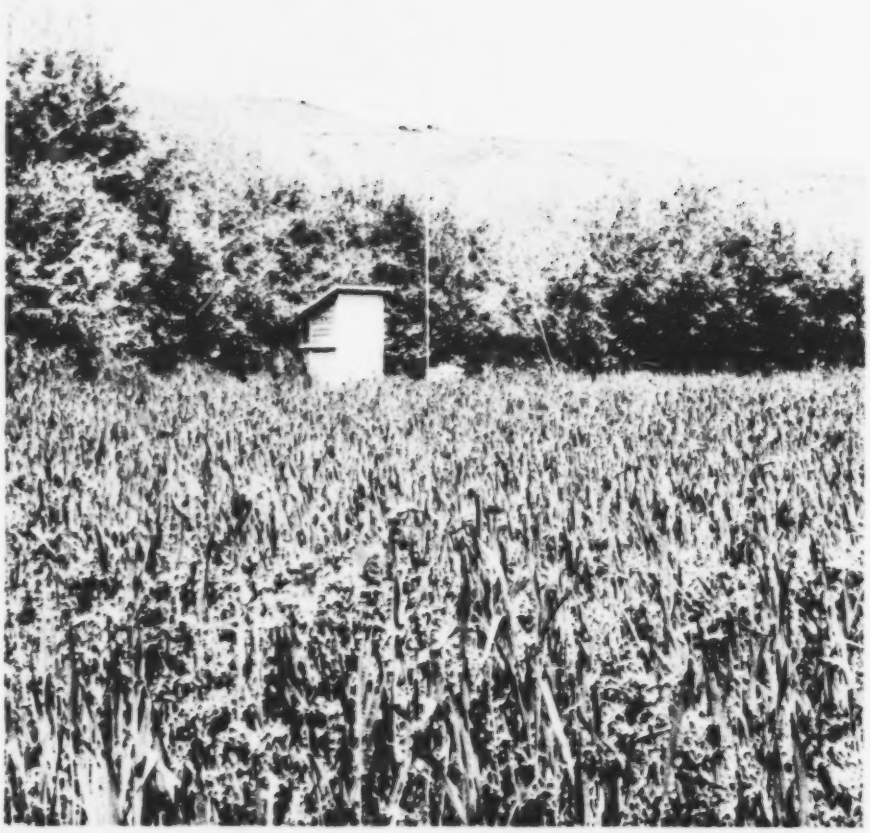


Fig. 5. Antenna mast at Paradise station.

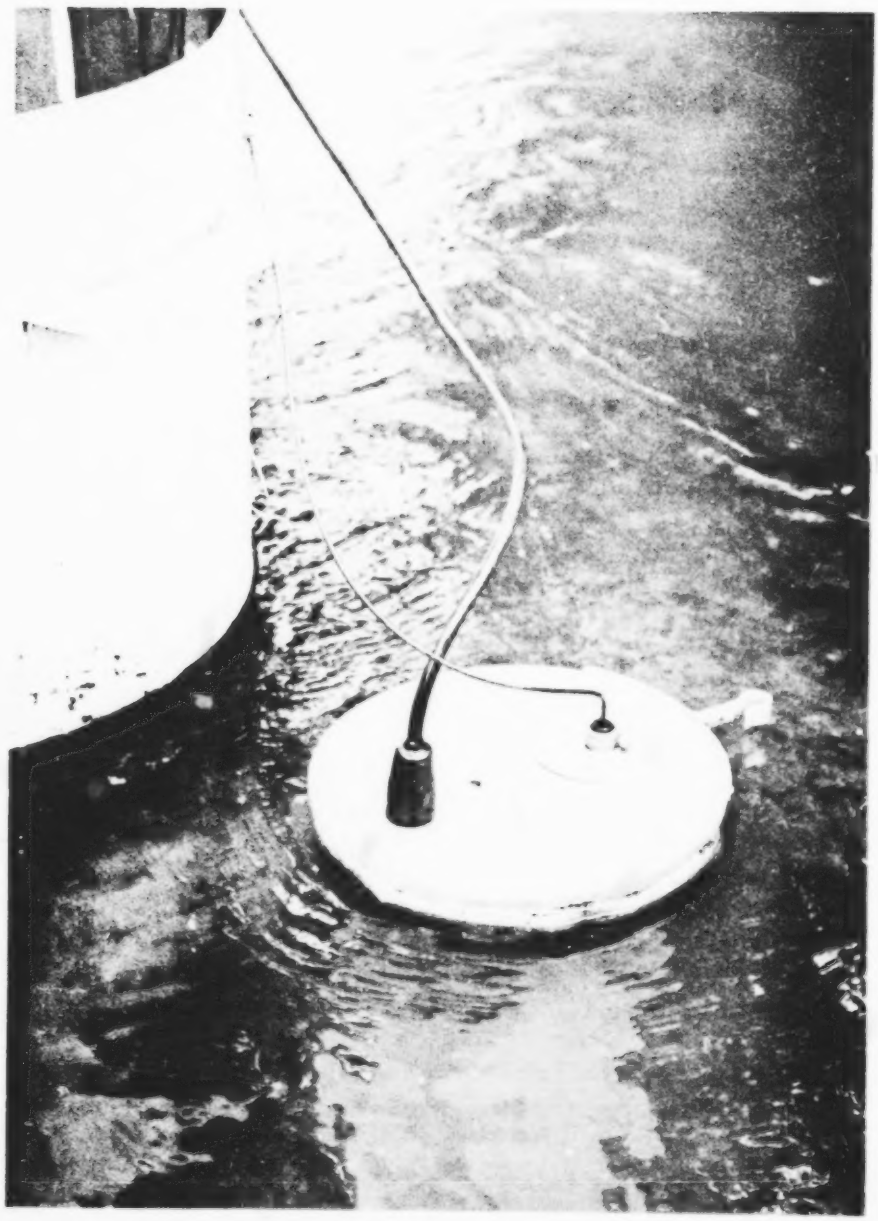


Fig. 6. Probe float at Paradise.

Fig. 7. Photograph of typical water quality sensors.

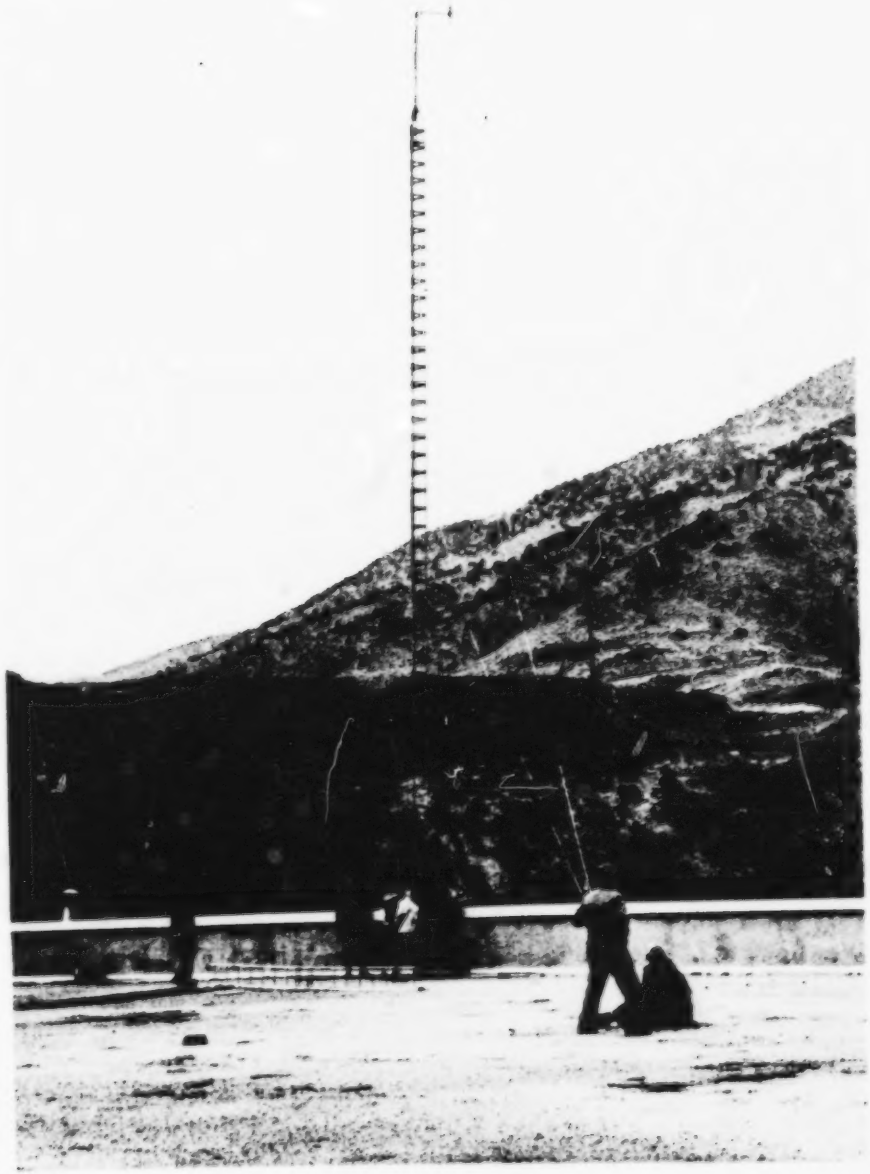


Fig. 8 Antenna tower at base station.

monitored by a speaker and quantified by a digital counter. Calibration curves are used to convert radio frequencies to dimensional parameter values. The base station also has a signal generator to produce the different tones necessary to call the two stations.

A pictorial representation of the base station and one remote site is shown in Fig. 9.

Originally, it was intended to store the data in a punched paper tape system at the Utah Water Research Laboratory; however, this storage system is unavailable to date and so the data was handled manually.

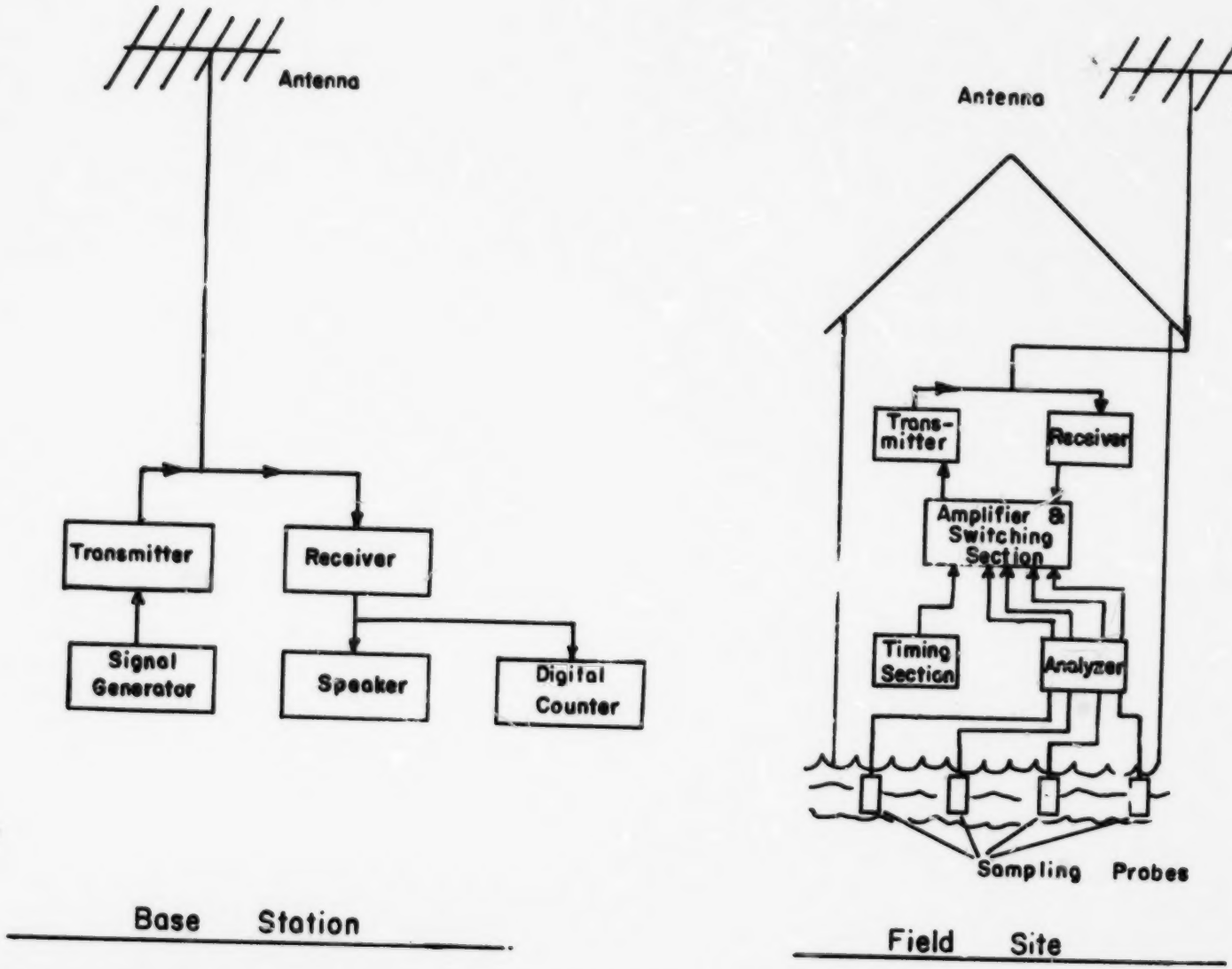


Fig. 9. Pictorial representation of a base station and one remote site.

DETAILED TECHNICAL DESCRIPTION

Field System Components

Sensors and analyzers

Commercially available water quality sensing equipment was purchased for the field systems. Two analyzers for each parameter were purchased; and, where possible, different manufacturers were selected so that different system designs could be evaluated. The availability of battery operated instrumentation suitable for field service is limited and of recent development. Refinement of some of the systems will undoubtedly occur as problem areas are detected in actual operating situations.

Two dissolved oxygen analyzer-sensor systems were obtained; the Electronic Instruments Limited (EIL) Model 15A System and the Weston and Stack Model 3000 Analyzer and Model 40 Probe with a Model A-25 Sampler. Both systems operate on the polarographic cell-selective membrane principle, i.e., the oxygen dissolved in the water diffuses through the semi-permeable membrane where it is reduced at the cathode to give a voltage proportional to the concentration (partial pressure) of oxygen in the water. The voltage generated is temperature dependent so it is necessary to provide for compensation. Both systems are equipped with a thermistor and associated circuitry

for automatic temperature compensation and independent measurement of temperature.

The EIL unit uses a concentric cylinder design. The inner lead anode is enclosed in a porous polyvinylchloride (PVC) shield that insulates the anode from the hollow surrounding silver cathode. The porous PVC insulator also allows the potassium bicarbonate electrolyte to form a conducting path between the electrodes. The entire assembly is covered by a polythene membrane which is permeable to oxygen but not to interfering ions. The Model 15A unit indicates percent saturation where 100 percent represents the partial pressure of oxygen in water saturated with air at 760 mm pressure. A temperature scale is provided on the instrument meter. Separate external recorder (telemetry) outputs are provided for both oxygen and temperature and these can be used simultaneously.

This dissolved oxygen meter has proven reliable and consistent in measuring both oxygen and temperature. It has only been necessary to change batteries twice during an operating period of eight months. During the same period, the probe has been renewed twice. The renewal process consists of replacing the consumable lead anode and replacing the membrane. Very little drift in the probe calibration has been experienced between weekly maintenance periods except as the probe approached the need for renewal. Cleaning of the probe during the weekly maintenance has appeared to be sufficient. No fouling has occurred between maintenance visits.

The Weston and Stack Model 40 probe uses the same principles of operation as the EIL unit but incorporates a different design. A convex platinum cathode is covered by an F. E. P. Teflon membrane. The lead anode is located in a large potassium iodide electrolyte reservoir above the cathode. The probe incorporates a thermistor for temperature compensation and temperature measurement. The Model 3000 analyzer indicates the dissolved oxygen in milligrams per liter with a 0 to 15 scale and a recorder output is provided. A temperature scale of 0 to 50° C is also indicated but no means are provided to externally obtain temperature data simultaneously with the oxygen information. To provide temperature data for telemetry, it was necessary to install a separate thermistor system. The Model 25 sampler mounts with the probe unit and consists of a waterproof motor which drives a Teflon cleaner-agitator assembly to clean the probe membrane and maintain a sufficient flow past the membrane to insure proper measurement of dissolved oxygen. A drawback of the sampler unit is that the motor operates only on 60 cps 110 V AC. For installation in the field a small inverter was used to convert the DC supplied battery power. To conserve battery life, the sampler unit was only activated when the station was actively transmitting data to the base station.

The Weston and Stack system has operated satisfactorily in the field for three months without any major problems. The need for AC power, however, is an annoying problem.

The measurement of pH was accomplished by using an Electronic Instruments Limited Model 90A and an Analytical Instruments Model 30. Both systems use permeable glass membrane probes with self-contained reference electrodes.

Temperature compensation in the Model 90A is not automatic but is manually adjusted for different liquid temperature ranges. Accuracy of measurement is stated as ± 0.1 pH for ± 10°C over the range of 4 - 10 pH. The EIL Model 90A unit has a rather large and cumbersome probe assembly for field service in rivers. This unit was a continuous source of difficulty for telemetry application. It was very sensitive to radio frequency pickup during the transmission cycle because it had an indirect ground reference. In a partially successful attempt to resolve the difficulty, a differential amplifier was used on the output to provide a balanced load. Finally a different probe (of another manufacturer) was used with the EIL analyzer, but many of the same problems still occurred.

The Analytical Instruments Model 30 has automatic temperature compensation. The unit includes a small recorder with a 5 to 10 pH range besides external signal provision. This probe will operate without servicing for a month

Only one type of conductivity meter was used, the Beckman RQ-2. The Model RQ-2 unit includes automatic temperature compensation to adjust all readings to the common standard temperature of 25°C. The system has a built-in chart recorder and no provision for external data

pick off. The recording pen is mechanically positioned by a balancing servo-mechanism. In order to telemeter, a potentiometer was installed which could be driven by the recording pen positioning mechanism.

Two recurring difficulties were encountered with the conductivity meter. Batteries were consumed by the system at a much faster rate than the battery usage rates of any of the other systems, and the probe required frequent replatinization to operate properly. The first problem appeared to be a result of excessive cycling of the self-balancing mechanism which reduced battery life. Ways to eliminate or live with the second problem have not been fully studied, but experimentation is continuing. Another unusual difficulty experienced was sticking of the contacts on the micropositioning relay. Three of these units were found to be defective before one was found that worked satisfactorily.

Data handling circuits

The various sensors and analyzers previously described produce a variety of output voltages and currents with different source impedances. The voltage controlled oscillator (VCO) which converts these inputs into corresponding audio frequencies has a range of 0 - 10 volts, but due to the limitations of the associated radio frequency equipment, only the 0 - 5 volt section of range is utilized. The response rate of the VCO is such that it will change frequency from 0 to 5 KH_z in less than 200 microseconds. Since all of the parameters being measured vary at very low rates, the VCO response rate is more than adequate. The

data handling circuits accept and convert the analyzer outputs into appropriate voltage levels for the VCO. The VCO output frequency modulates the rf carrier which is transmitted to the central data collection site. The system electronic circuitry is divided into three major subsystems: Amplifier and switching circuits, timing section, and rf section. Interconnection between these subsystems is shown in Fig. 10.

Amplifier and switching circuits. Schematic diagrams of the amplifier and switching circuits for the two stations are shown in Figs. 11 and 12. The two systems are very similar with only a few modifications being required as dictated by the different analyzers. The Wellsville system will be described in detail with only the differences being described for the Paradise circuit.

Selection of the various parameters is made by rotary switch, K3. This switch is activated through contact, K4A, upon the firing of the silicon controlled rectifier, Q3. This switch is sequenced through its 12 positions by the timing section. Details on this control will be found in the timing section description.

As shown on the diagram, relays 8 and 9 are activated when power is applied to the wiper of K3. These two relays control the power supplied to the voltage controlled oscillator (VCO) and the operational amplifiers. By closing only during the readout period, they greatly extend the battery life.

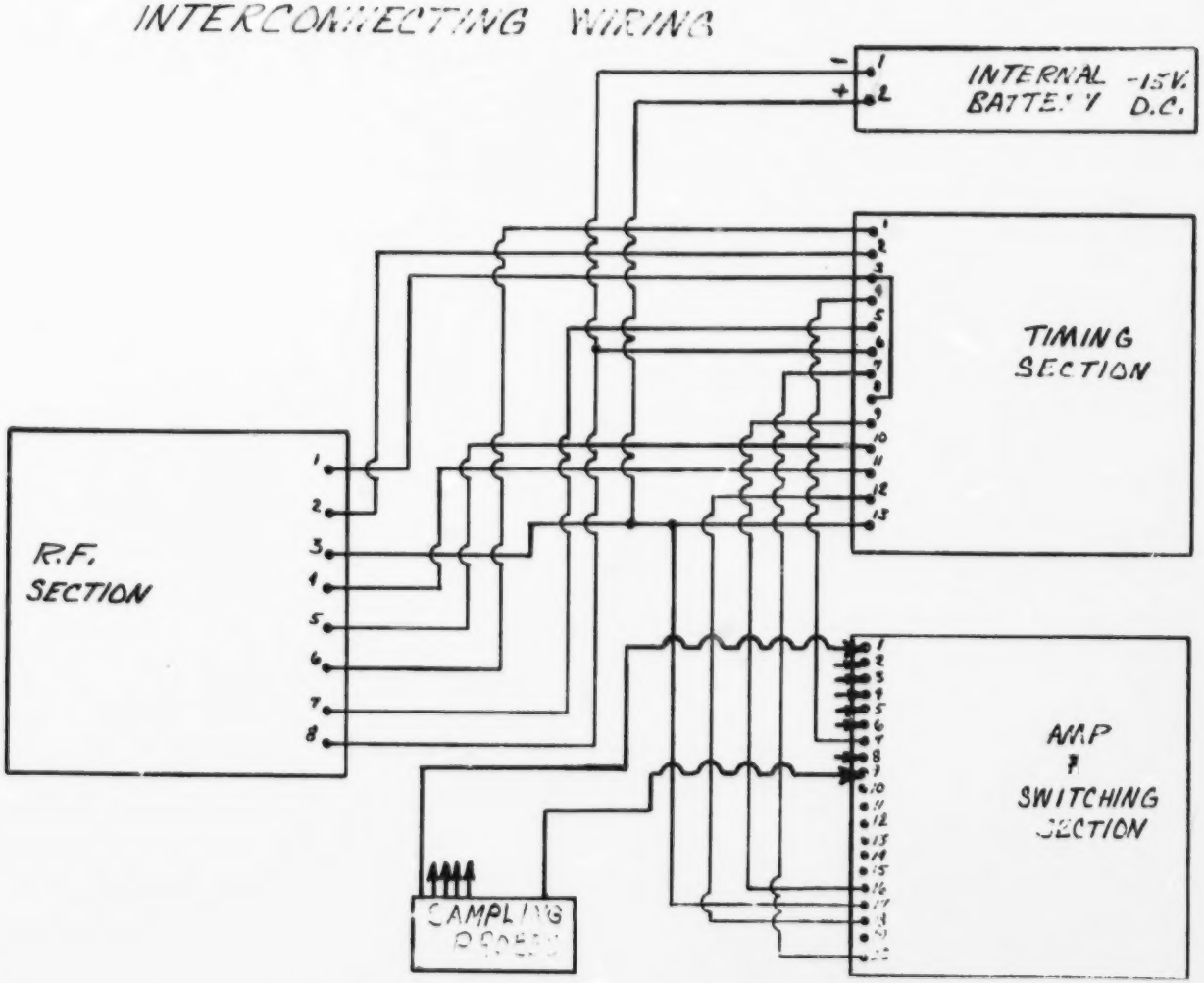
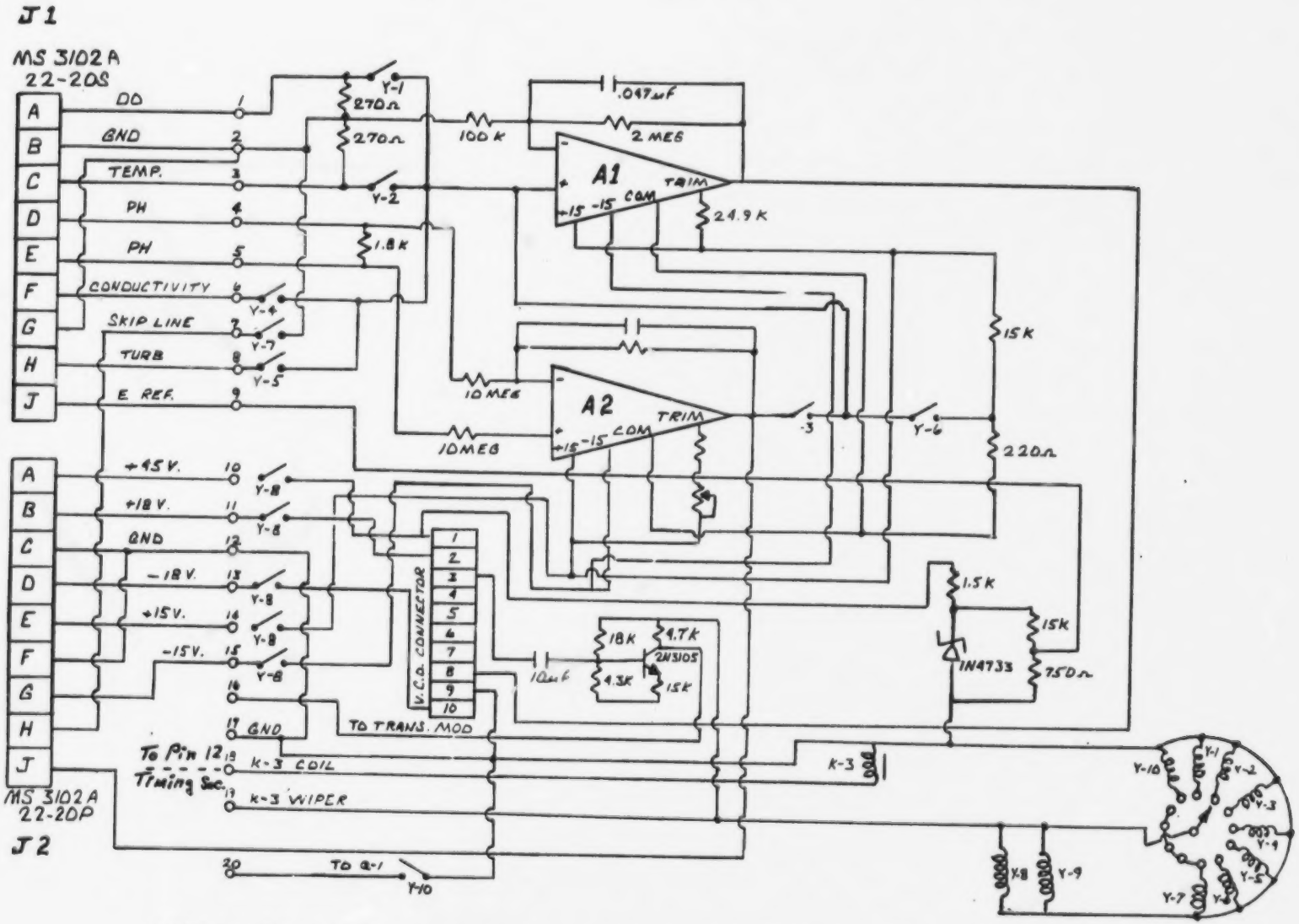
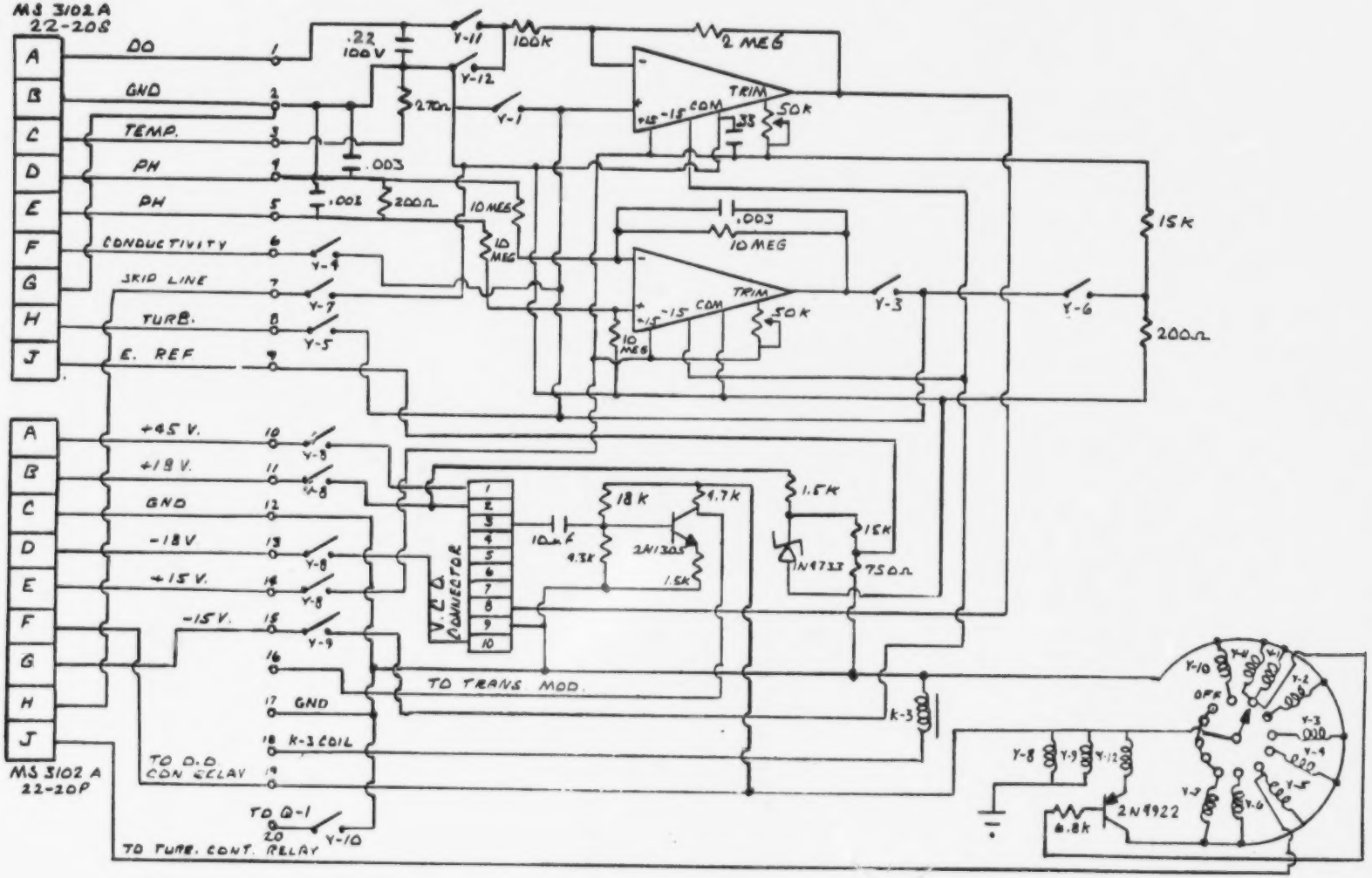


Fig. 10. Block diagram of field site electronics.



WELLSVILLE AMPLIFIER AND SWITCHING SECTION

Fig. 11. Schematic diagram of Wellsville amplifier and switching section.



PARADISE AMPLIFIER AND SWITCHING SECTION

Fig. 12. Schematic diagram of Paradise amplifier and switching section.

Operational amplifier A1 is connected as a non-inverting amplifier with a gain of 20. This gain is determined by the ratio of the 2 megohm feedback resistor and the 100K ohm resistance to ground and is independent of amplifier characteristics over a wide range of voltage and open loop gain conditions. The output of A1 is fed directly as input to the voltage controlled oscillator which converts voltage levels into corresponding frequencies. For this particular VCO the conversion is linear and starts from zero cycles at zero volts and would go to 10 KH_z at 10 volts although no input is allowed to exceed 5 volts and the usual operating levels are about 2 - 3 volts.

The first four positions of K3 are stepped through without pause. These are positions for potential expansion of the system to accept four more sensor inputs, on step 5 voltage is applied to the coil of relay Y-6 thereby actuating it and closing contacts Y-6 in the voltage monitoring circuit.

The voltage divider in the monitoring circuit reduces the +15 V to .22 volts which is then amplified to 4.4 volts through the operational amplifier. This "divide down and amplify" procedure is used to give an overall check of the operational amplifier and the +15 voltage supply as well as the VCO and the rf transmission system.

The next step of K3 opens Y-6 and closes Y-5. This connection is set up for turbidity measurement although the turbidity parameter was not monitored at this station.

The next step of K3 closes Y-4 and feeds conductivity data to the VCO. The conductivity information is taken from the wiper of an auxiliary potentiometer mounted in the conductivity meter. The potentiometer is driven by the same mechanical motion that drives the pen as it moves across the chart of the RQ-2 conductivity meter. Reference voltage for this potentiometer is obtained from the Zener regulated reference source through pin J of connector J1.

Following conductivity, the step switch energizes Y-3 to initiate a pH data sample. The output of the pH meter is differentially connected into the additional operational amplifier A2 because the pH probe is a high impedance device and has a floating output not referenced to ground. This floating output makes pH the most complicated parameter to telemeter under the present conditions. The high impedance makes the probe subject to pick up of extraneous signals and noise. A redesign of the pH electronic circuit should solve these difficulties.

The next step of K3 energizes Y-2 and closes the temperature input circuit. The temperature is measured by the Electro Instruments Ltd. dissolved oxygen system which provides temperature output.

The circuit is so designed that it will drive 1 ma. into 400 ohms at 30° C (full-scale meter reading). Only part of this .4 volt output is needed for telemetry so a 270 ohm load is used which gives .27 volts at 30° C. When passed through the X20 operational amplifier this becomes 5.4 volts to be fed to the VCO at full scale or 30° C. The water temperature is usually below 20° C so the largest voltage is about 3.6 volts.

The next K3 step energizes Y-1 and feeds the dissolved oxygen data into the telemetering system. Like the temperature measurement, the D.O. output at full scale is 1 ma. into 400 ohms. Since this much voltage is not required, a 270 ohm load is used and produces 5.4 volts at full-scale output.

The last step of K3 energizes Y-10 whose contacts then short the base of Q1 to ground thereby cutting off the current through Q1 and de-energizing K1. As K1 returns to its de-energized position, it switches the rf system from transmit to receive (contacts K1B) and simultaneously switches the antenna connection from the transmitter to the receiver (contacts K1A).

This completes the data transmission cycle and restores the system to standby operation ready to receive the next interrogation tones

Timing section. A schematic diagram of this section is shown in Fig. 13. In order to describe the operation of the timing section, one complete data gathering cycle will be described in detail. The sequence is initiated by two audio tones transmitted from the base station. These two tones (522 Hz and 475 Hz for the Wellsville station and 522 Hz and 450 Hz for the Paradise station) are fed in series from the receiver to the Bramco resonant reed relay. The high frequency tone is transmitted first followed immediately by the low tone.

The high frequency reed contact is connected to the base circuit of Q4 through a 100K resistor. As this reed vibrates, it touches

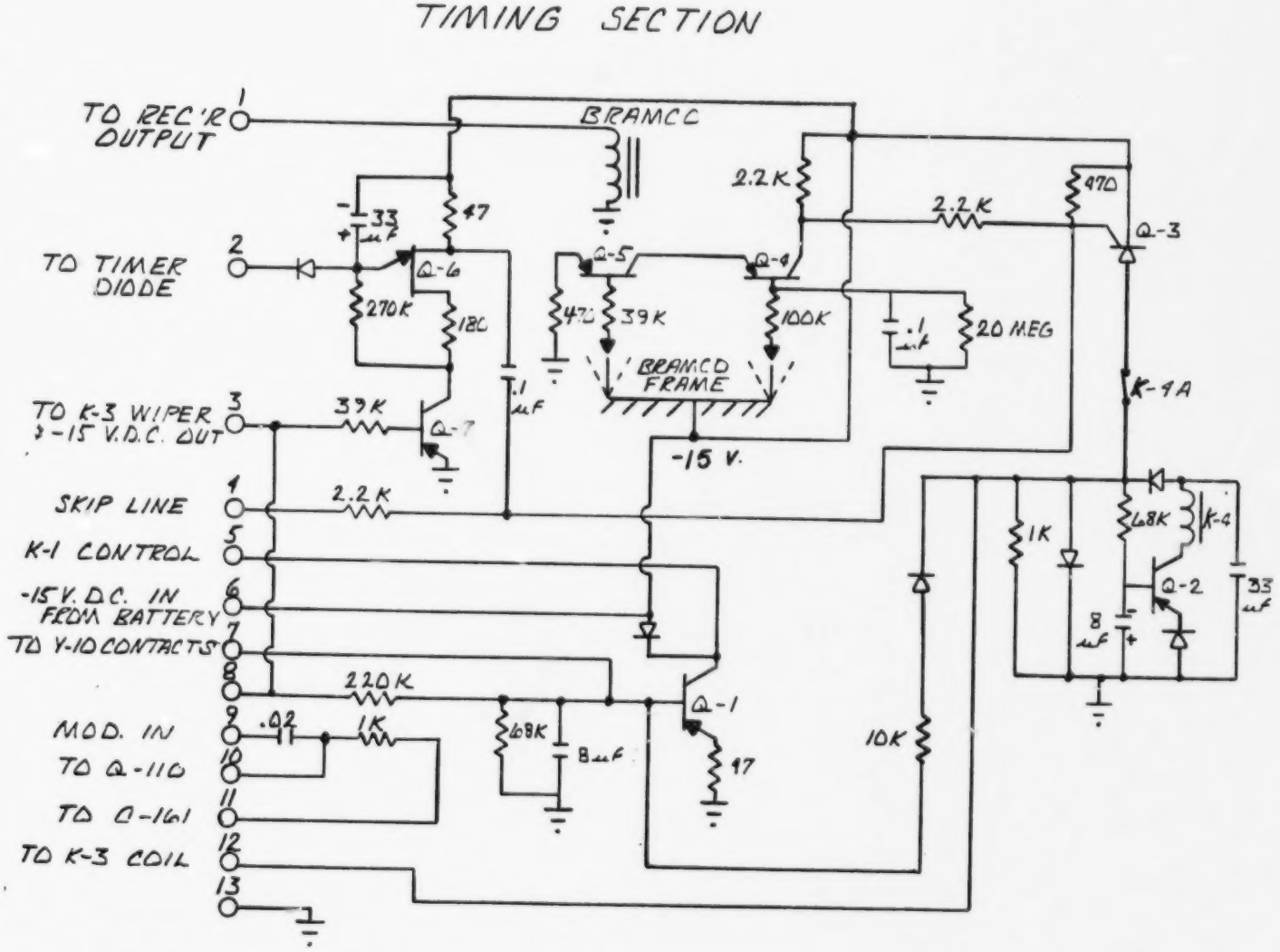


Fig. 13. Schematic diagram of timing section.

the contact and feeds -15 volts onto the base of Q4 thereby switching it to a conducting state and simultaneously charging the .1 μfd capacitor so that the transistor will be held in the conducting state for about 2 to 5 seconds. During this period the tone is changed to 475 (or 450) as required and the reed vibrating connects -15 volts to the base of Q5 and thus causes it to switch to a conducting state. With Q4 and Q5 both conducting, the gate of Q3 is grounded and causes Q3 (a silicon controlled rectifier) to fire and assume a conducting state. The firing of Q3 applies -15 volts to relays K4, K3, and K1. Relay K4 is controlled by Q2 and its associated RC network such that it is activated about 1/2 second after Q3 fires. This relay when activated opens the -15 V line which then allows Q3 to reset itself. With Q3 reset, even though contacts K4A close when K4 is deactivated, the -15 volt line has no voltage on it on the anode side of Q3. Before K4A contacts open the -15 volts through Q3, contacts K4A, a diode and a 10 K resistor cause Q1 to conduct and close K1. K1 is latched up by contacts K1B closing and feeding -15 V through a voltage divider onto the base of Q1. Voltage at the K1B contact is removed from the normally closed contact and thus releases the timer diode so that the timing circuit connected to Q6 begins charging through Q7 which was made conducting when the -15 volts was applied by K1B contact through the 39 K resistor to its base.

When Q6 (a unijunction transistor) fires, a positive pulse is fed through a .1 μfd capacitor onto the skip line where it fires Q3

to start the timing sequence over and step K3 on to sample the next parameter. This process continues until finally K3 steps to the contact which closes Y-10. When Y-10 is activated its contacts short the base of Q1 to ground and thus deactivate K1 which restores the system to a standby condition ready for the next interrogation tones.

The "skip line" terminal is brought out through a 2.2K resistor so that the system can be turned on at the site. Grounding the skip line causes the gate voltage to move in a positive direction from -15V and thus turns on the SCR and initiates a cycle as described above. Each time the skip line is grounded K3 steps once so that the sequence can be advanced to any desired parameter without waiting for Q6 to time out on each step. No provision has been made to lock the output on a given parameter since that is seldom desirable.

Rf section. The components contained in the rf section are shown in Fig. 14. The relay, K1, is mounted in this section to permit the use of short connecting wires into K1A contacts since they switch the antenna from receive to transmit. The entire rf system is housed in a separate box with feed through capacitors for all leads so that an effective rf shield is maintained. The receiver and transmitter units from a 2 watt hand-held Motorola HT-2 Handie Talkie set are used for reception and transmission in the telemetry system. They are both crystal controlled and operate on a frequency of 170.325 MHz.

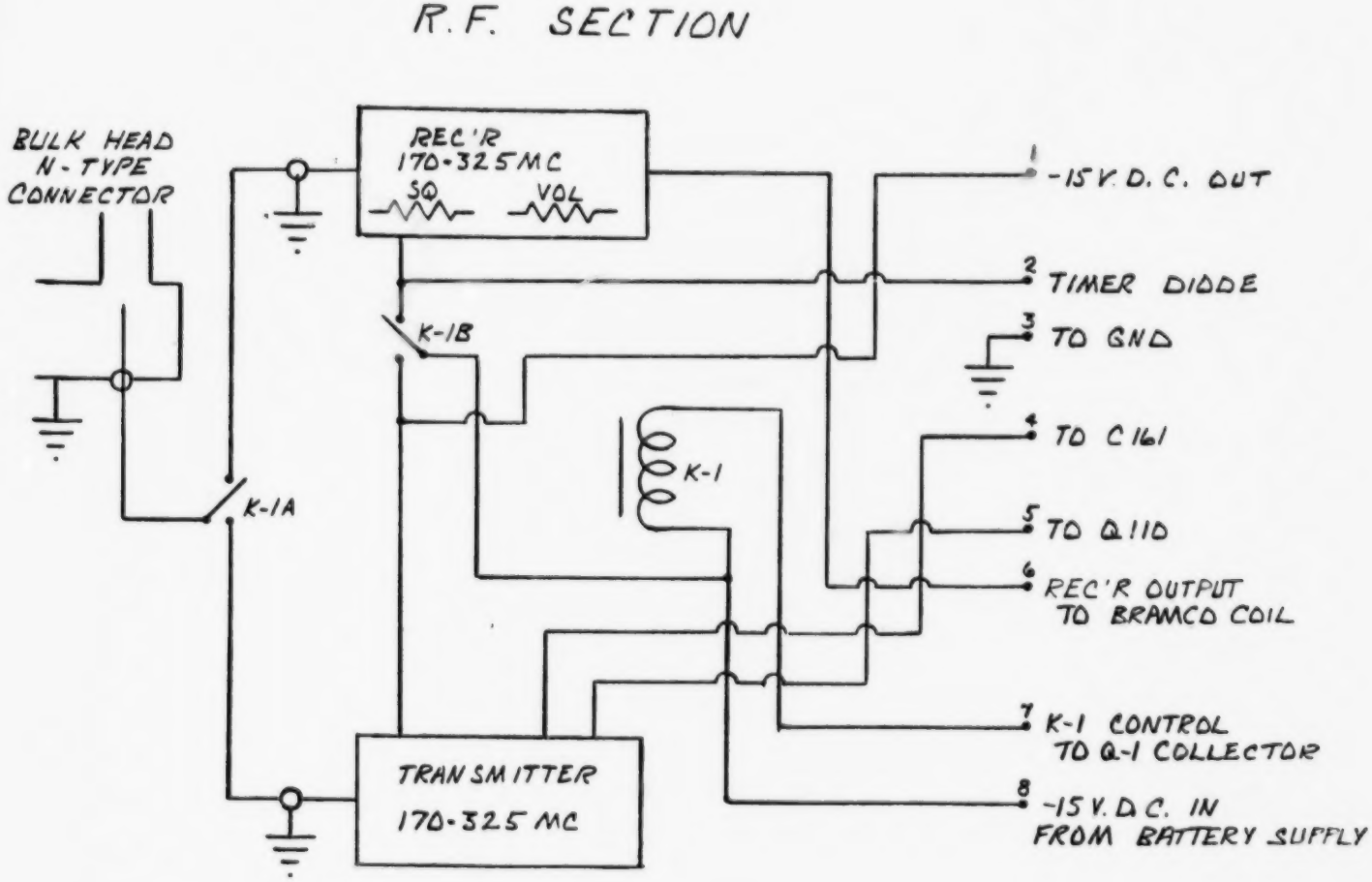


Fig. 14. Block diagram of rf section.

Base station system

The data gathering system used at the base station consists of a Motorola Consolette (25 watts transmitter power), a five element yagi antenna (with approximately 8 db gain), an H-P signal generator, an H-P counter, and a locally constructed remote monitoring and control system. Facilities are available at the Utah Water Research Laboratory to automatically initiate a read out and count and print the data. However, these facilities were not used for this project because of the small amount of data taken and the ease with which it could be recorded and analyzed manually. Some punched paper tape data recording equipment has been acquired by the laboratory, but it has not yet been placed in service. The five element yagi antenna, although quite directional, was used in this particular case because the two monitored sites were roughly on a radial line from the Utah Water Research Laboratory. In a general application, it would be desirable to use an omni-directional antenna. The two interrogating tones are generated in series by tuning the signal generator. These are monitored by the counter so that the exact frequency is transmitted in each case. The returning data signal is fed from the receiver to the monitor where it can be heard as well as counted. The frequency count for each parameter is written on a data sheet for later conversion to a particular value of physical variable being measured.

This conversion could be accomplished automatically by the use of a small computer.

SYSTEM EVALUATION

To evaluate the accuracy of the water quality analyzers and the telemetry of data, an on-site surveillance test was conducted. Operators were stationed at the two telemetry stations and at the base station for three successive days from 8 a.m. to 10 p.m. The operators at the two field stations recorded the parameter value indicated by each analyzer and conducted independent measurement of parameter values every half hour. Independent water temperature was measured by a glass-mercury thermometer and independent dissolved oxygen was determined on-site by a wet chemistry test (Winkler dissolved oxygen test). Water samples were collected every hour and brought to the laboratory to check conductivity and pH. The field operators initiated a telemetry transmission every half hour. The base station operator recorded the telemetered data and evaluated each parameter value from its calibration curve.

A comparison of on-site and telemetered data was made at the conclusion of the tests. The independently measured values of the parameters were taken as the standards. The analyzer readings and telemetry values were subtracted from the standard to give deviations. The average of the deviations was used as a measure of accuracy obtained during a days test. The results are shown in Table 1. Also included in the table are the largest deviations from the standard observed.

Table 1. On-site surveillance results.

Parameter	Average Deviation	Experimental Accuracy	Extreme Deviation
Temperature	0.5°C	±0.6°C	1.5°C
Dissolved Oxygen	0.2 mg/l	±0.15 mg/l	0.6 mg/l
Conductivity	15 μmhos/cm	±10 μmhos/cm	22 μmhos/cm
pH	0.18	±0.15	0.45

To obtain a position of comparison for evaluation, the experimental accuracy for each of the measuring techniques is indicated. For example, it was not possible to read the glass thermometer any closer than ±0.5°C, while the telemetered temperature could be read to within ±0.1°C. Consequently, the deviation of telemetered temperature from the standard was accurate to within ±0.6°C. It is significant to note that the average deviation observed was only 0.5°C.

The dissolved oxygen, temperature, and pH all exhibit diurnal cycles. Graphical representation of typical results for these three parameters are shown in Figs. 15, 16, and 17. The three means of measurement; telemetry, field instrument, and independent field analysis, are shown in each figure. The conductivity of the water was essentially constant throughout the tests and deviations were due to randomness.

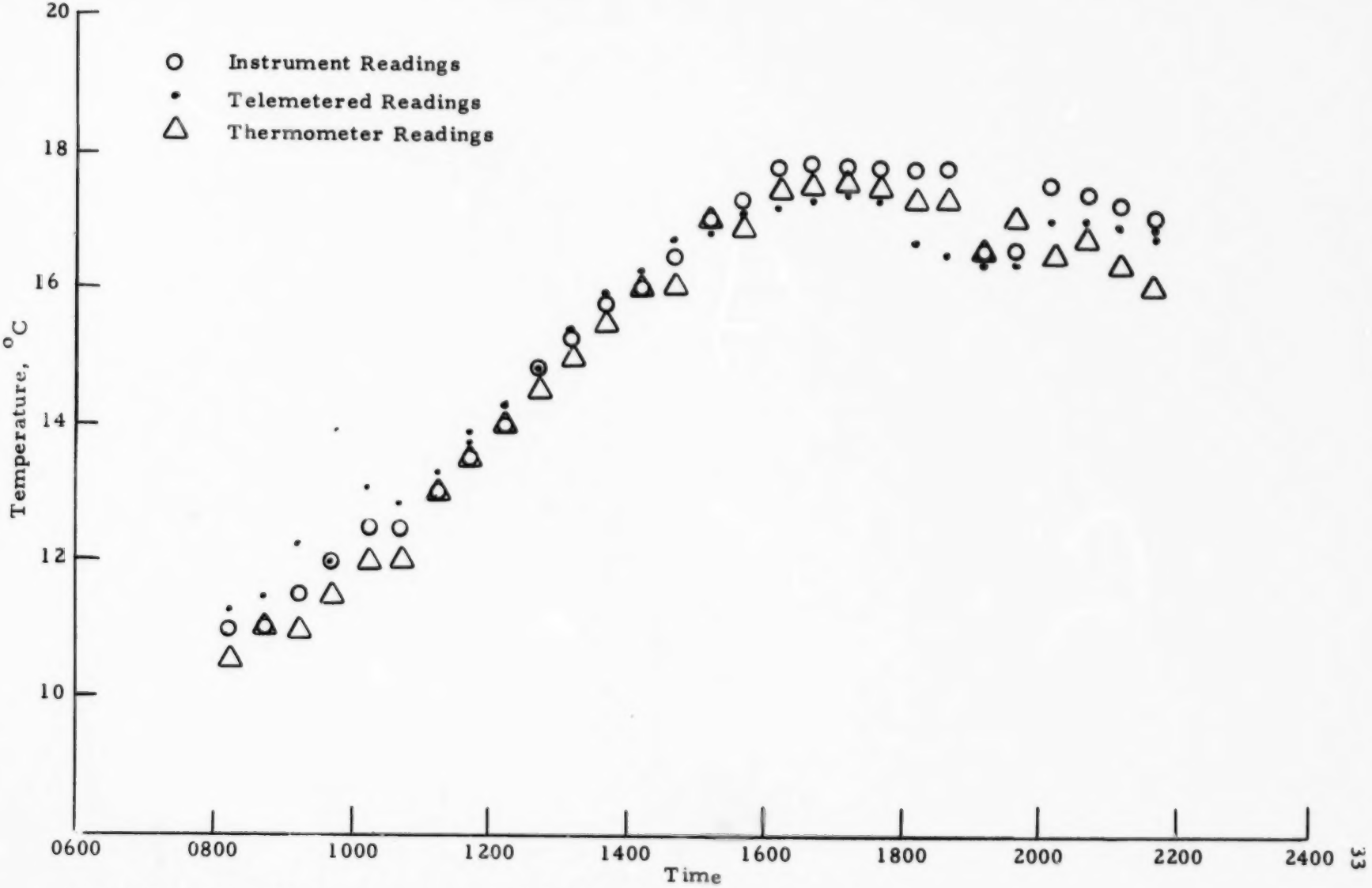


Fig. 15. Graph of temperature vs time for three measurement methods.

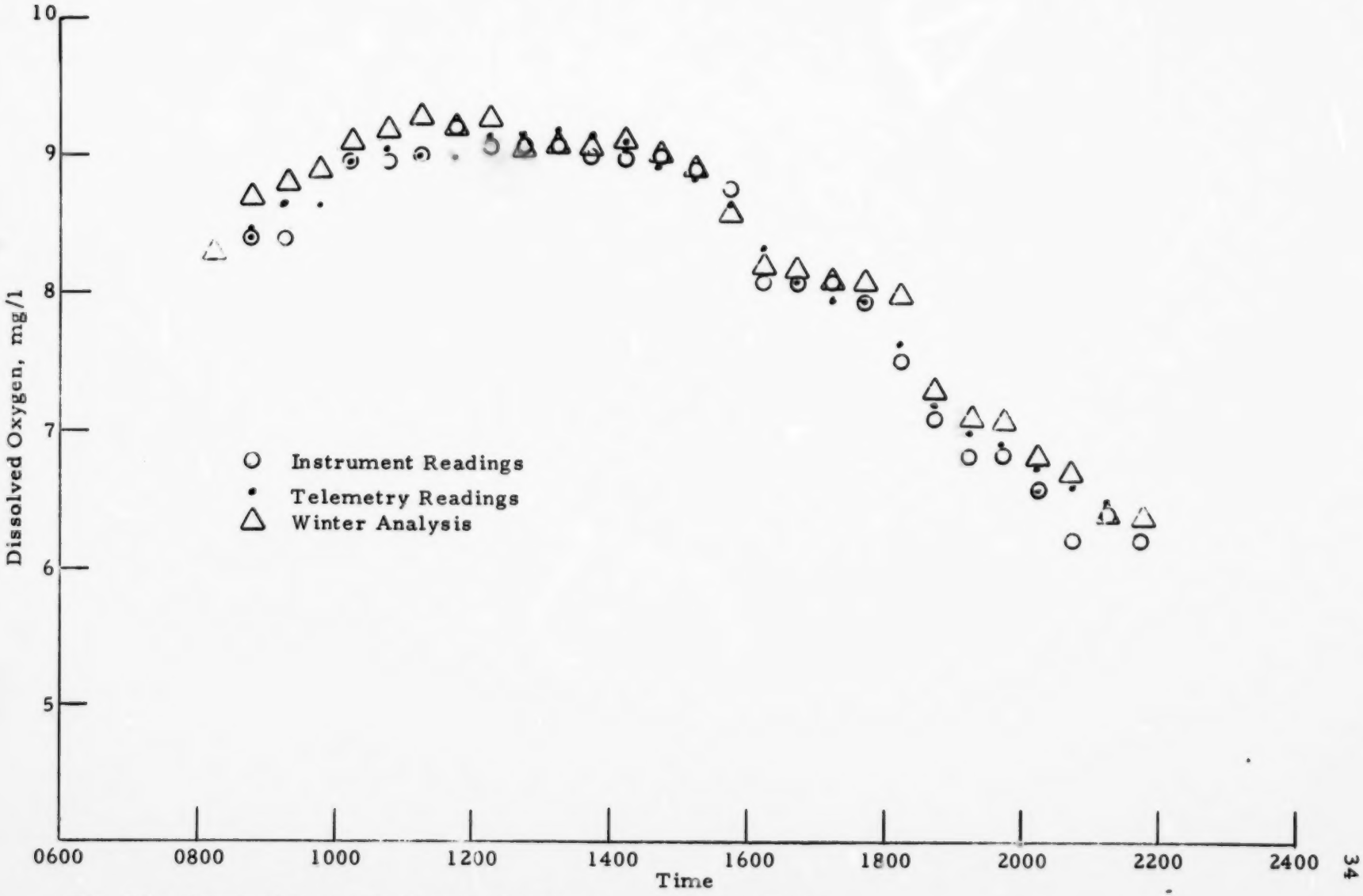


Fig. 16. Graph of D.O. vs time for three measurement methods.

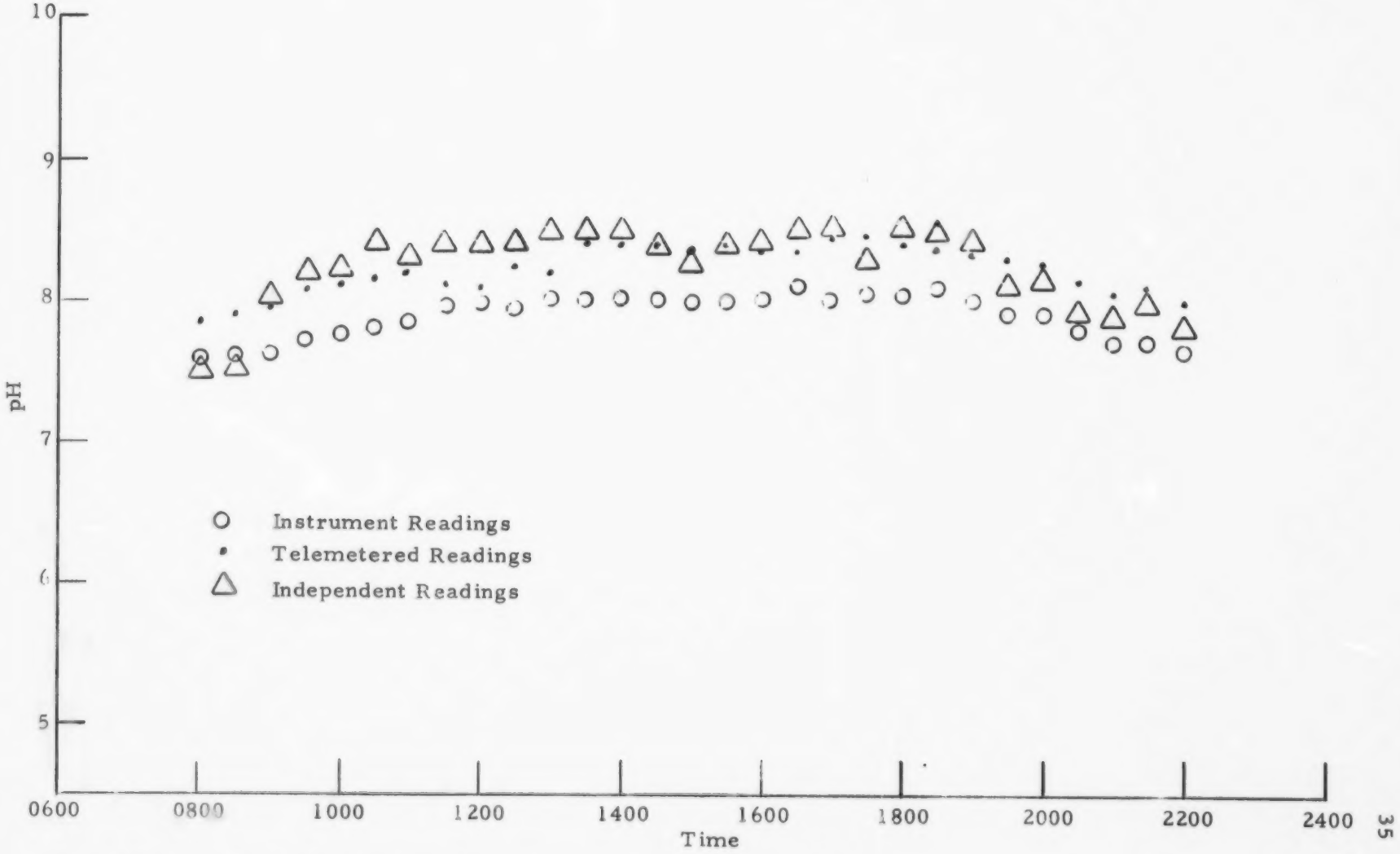


Fig. 17. Graph of pH vs time for three measurement methods.

COSTS

For a development project, the costs always exceed the unit cost for a production unit so that direct cost comparisons are misleading. The cost figures shown herein are given only to represent the order of magnitude of costs for given items and complete systems produced in quantity should cost considerably less. In addition the continuation of this project into the coming year has as one of its major goals the integration of much of the duplicated circuitry into one common unit which will produce further price reductions.

Equipment installed at Wellsville monitoring site:

Antenna and mast	$ 50.00
pH meter	900.00
Telemetry system	1,250.00
Voltage controlled oscillator	275.00
D.O. and temperature	890.00
Conductivity	1,000.00
Interface circuitry and fabrication	400.00
Shelter (includes construction and installation)	250.00
Batteries and other expendables	200.00
	$5,215.00

The above prices are for equipment only except in the case of the shelter and the interface circuitry fabrication.

Equipment installed at the Paradise monitoring station:

Antenna and mast	$ 75.00	
Telemetry system	1,250.00	
Voltage controlled oscillator	275.00	
pH meter	590.00	
Conductivity meter	1,000.00	
D.O. and temperature	1,760.00	(this is a Weston-Stack unit with motorized cleaning of the membrane)
Interface circuitry and fabrication	400.00	
Shelter (construction and installation)	250.00	
Voltage converter (for D.O.)	40.00	
Batteries and other expendables	200.00	
	$5,840.00	

The extra cost of the equipment at Paradise is not warranted by the experience to date. The difference is principally in the Dissolved Oxygen Meter and the self-cleaning feature does not appear to be necessary since the other D.O. meter operated satisfactorily with periodic servicing.

Equipment at the base station:

Antenna and 65' mast	$ 100.00
Consolette transmitter-receiver	500.00
Counter	575.00
Signal generator	275.00
Monitor and miscellaneous small parts	50.00
	$1,500.00

SUMMARY

This project has amply demonstrated that it is possible to telemeter data from remotely placed water quality sensors by radio frequency. The accuracy of this transmitted data has been verified and shown to be very close to the range of experimental accuracy possible with existing instrumentation. Because the field sites are totally battery operated and the transmission of data is performed by radio frequency, it is possible to locate field sites in remote locations without regard for power availability or telephone line accessibility. Maintenance of the field sites was performed weekly during the development of the system, but the longevity of batteries and probe calibration indicate that it may be possible to reduce maintenance visits to a less frequent schedule.

The cost per field site representing equipment and installation costs and excluding development costs, is about $5,500. This low cost can be reduced even further by developing a system that integrates much of the duplicative circuit found in the separate commercial analyzers being used presently.

Two instrument problems require further analysis. One pH meter was not compatible in its operation with radio frequency telemetry, and the conductivity analyzers required excessive maintenance due to high battery consumption and need for frequent probe replatinization.

One effort of the one-year continuation grant will be to eliminate the aforementioned problems and evaluate various sensor designs for compatibility with the telemetry system and maintainability for long periods of unattended operation. In addition to sensor evaluation, the continuation grant will develop a simplified system in which the electronic conditioning circuitry for the various sensors will be integrated into a single unit. This will facilitate use of a single battery system and lower equipment and battery cost.

The system development described in this report is only the first step in the establishment of an effective data gathering network. The logical end use of this type of system will be its application to monitoring of total river basin systems for management and/or control purposes. For a river basin, several field stations will be required and frequent sampling will be necessary. In such a multi-station application, some kind of automatic central data acquisition system will be required to handle the multitude of data obtained and reduce it to usable form in a reasonable period of time.